SLOVENSKI STANDARD

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Eurocode 2 - Design of concrete structures - Part 3: Liquid retaining and containment structures

Eurocode 2 - Bemessung und Konstruktion von Stahlbeton- und Spannbetontragwerken - Teil 3: Silos und Behälterbauwerke aus Beton

Eurocode 2 - Calcul des structures en béton - Partie 3: Silos et réservoirs

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EN 1992-3

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English Version

Eurocode 2 - Design of concrete structures - Part 3: Liquid retaining and containment structures

Eurocode 2 - Calcul des structures en béton - Partie 3: Silos et réservoirs

Eurocode 2 - Bemessung und Konstruktion von Stahlbeton- und Spannbetontragwerken - Teil 3: Stütz- und Behälterbauwerke aus Beton

This European Standard was approved by CEN on 24 November 2005.

CEN members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration. Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the Central Secretariat or to any CEN member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CEN member into its own language and notified to the Central Secretariat has the same status as the official versions.

CEN members are the national standards bodies of Austria, Belgium, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland and United Kingdom.

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Foreword

This European Standard (EN 1992-3:2006) has been prepared by Technical Committee CEN/TC 250 "Structural Eurocodes", the secretariat of which is held by BSI.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by December 2006, and conflicting national standards shall be withdrawn at the latest by March 2010.

This Eurocode supersedes ENV 1992-4.

CEN/TC 250 is responsible for all Structural Eurocodes.

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland and the United Kingdom.

Background of the Eurocode programme

See EN 1992-1-1.

Eurocode programme

See EN 1992-1-1.

Status and Field of application of Eurocodes

See EN 1992-1-1.

National Standards implementing Eurcodes

See EN 1992-1-1.

Links between Eurocodes and harmonized technical specifications (ENs and ETAs) for products

See EN 1992-1-1.

Additional information specific to EN 1992-3 and link to EN 1992-1-1

The scope of Eurocode 2 is defined in 1.1.1 of EN 1992-1-1 and the scope of this Part of Eurocode 2 is defined in 1.1.2. Other Additional Parts of Eurocode 2 which are planned are indicated in 1.1.3 of EN 1992-1-1; these will cover additional technologies or applications, and will complement and supplement this Part. It has been necessary to introduce into EN 1992-3 a few clauses which are not specific to liquid retaining or containment structures and which strictly belong to Part 1-1. These are deemed valid interpretations of Part 1-1 and design complying with the requirements of EN 1992-3 are deemed to comply with the principles of EN 1992-1-1.

It should be noted that any product, such as concrete pipes, which are manufactured and used in accordance with a product standard for a watertight product, will be deemed to satisfy the requirements, including detailing, of this code without further calculation.

There are specific regulations for the surfaces of storage structures which are designed to contain foodstuffs or potable water. These should be referred to as necessary and their provisions are not covered in this code.

In using this document in practice, particular regard should be paid to the underlying assumptions and conditions given in 1.3 of EN 1992-1-1.

The nine chapters of this document are complemented by four Informative Annexes. These Annexes have been introduced to provide general information on material and structural behaviour which may be used in the absence of information specifically related to the actual materials used or actual conditions of service.

As indicated above, reference should be made to National annexes which will give details of compatible supporting standards to be used. For this Part of Eurocode 2, particular attention is drawn to EN 206-1 (Concrete - performance, production, placing and compliance criteria).

For EN 1992-3, the following additional sub-clauses apply.

This Part 3 of Eurocode 2 complements EN 1992-1-1 for the particular aspects of liquid retaining structures and structures for the containment of granular solids.

The framework and structure of this Part 3 correspond to EN 1992-1-1. However, Part 3 contains Principles and Application Rules which are specific to liquid retaining and containment structures.

Where a particular sub-clause of EN 1992-1-1 is not mentioned in this EN 1992-3, that sub-clause of EN 1992-1-1 applies as far as deemed appropriate in each case.

Some Principles and Application Rules of EN 1992-1-1 are modified or replaced in this Part, in which case the modified versions supersede those in EN 1992-1-1 for the design of liquid retaining or containment structures.

Where a Principle or Application Rule in EN 1992-1-1 is modified or replaced, the new number is identified by the addition of 100 to the original number. Where a new Principle or Application Rule is added, it is identified by a number which follows the last number in the appropriate clause in EN 1992-1-1 with 100 added to it.

A subject not covered by EN 1992-1-1 is introduced in this Part by a new sub-clause. The sub-clause number for this follows the most appropriate clause number in EN 1992-1-1.

The numbering of equations, figures, footnotes and tables in this Part follow the same principles as the clause numbering as described above.

National annex for EN 1992-3

This standard gives values with notes indicating where national choices may have to be made. Therefore the national Standard implementing EN 1992-3 should have a National annex containing all Nationally Determined Parameters to be used for the design of liquid retaining and containment structures to be constructed in the relevant country.

National choice is allowed in EN 1992-3 through the following clauses:

7.3.1 (111)

7.3.1 (112)

7.3.3

8.10.3.3 (102) and (103)

9.11.1 (102)

Section 1 General

1.1 Scope

Replacement of clause 1.1.2 in EN 1992-1-1 by:

1.1.2 Scope of Part 3 of Eurocode 2

(101)P Part 3 of EN 1992 covers additional rules to those in Part 1 for the design of structures constructed from plain or lightly reinforced concrete, reinforced concrete or prestressed concrete for the containment of liquids or granular solids.

(102)P Principles and Application Rules are given in this Part for the design of those elements of structure which directly support the stored liquids or materials (i.e. the directly loaded walls of tanks, reservoirs or silos). Other elements which support these primary elements (for example, the tower structure which supports the tank in a water tower) should be designed according to the provisions of Part 1-1.

(103)P This part does not cover:

— Structures for the storage of materials at very low or very high temperatures

— Structures for the storage of hazardous materials the leakage of which could constitute a major health or safety risk.

— The selection and design of liners or coatings and the consequences of the choice of these on the design of the structure.

— Pressurised vessels.

— Floating structures

— Large dams

— Gas tightness

(104) This code is valid for stored materials which are permanently at a temperature between –40 °C and +200 °C.

(105) For the selection and design of liners or coatings, reference should be made to appropriate documents.

(106) It is recognised that, while this code is specifically concerned with structures for the containment of liquids and granular materials, the clauses covering design for liquid tightness may also be relevant to other types of structure where liquid tightness is required.

(107) In clauses relating to leakage and durability, this code mainly covers aqueous liquids. Where other liquids are stored in direct contact with structural concrete, reference should be made to specialist literature.

1.2 Normative references

The following normative documents contain provisions that, though referenced in this text, constitute provisions of this European Standard. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this European Standard are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies.

EN 1990, Eurocode, *Basis of structural design*

EN 1991-1-5, Eurocode 1, *Actions on structures – Part 1-5: General Actions – Thermal actions*

EN 1991-4, Eurocode 1, *Actions on structures – Part 4: Silos and tanks*

EN 1992-1-1, Eurocode 2, *Design of concrete structures – Part 1.1: General rules and rules for buildings*

EN 1992-1-2, Eurocode 2, *Design of concrete structures – Part 1.2: General rules – Structural fire design*

EN 1997, Eurocode 7: *Geotechnical design*

1.6 Symbols

Addition after 1.6

1.7 Special symbols used in Part 3 of Eurocode 2

Latin upper case symbols

R_{ax} factor defining the degree of external axial restraint provided by elements attached to the element considered

R_m factor defining the degree of moment restraint provided by elements attached to the element considered.

Latin lower case symbols

f_{ctx} tensile strength, however defined

f_{ckT} characteristic compressive strength of the concrete modified to take account of temperature.

Greek symbols

ε_{av} average strain in the element

ε_{az} actual strain at level z

ε_{iz} imposed intrinsic strain at level z

ε_{Tr} transitional thermal strain

ε_{Th} free thermal strain in the concrete

Section 2 Basis of design

2.1 Requirements

2.1.1 Basic requirements

Addition following (3):

(104) The design situations to be considered should comply with EN 1990, EN 1991-4 and EN 1991-1-5, chapter 3. In addition, for liquid retaining and containment structures made with concrete, the following special design situations may be relevant:

— Operating conditions implying patterns of discharge and filling;

— Dust explosions;

— Thermal effects caused, for example, by stored materials or environmental temperature;

— Requirements for testing of reservoirs for watertightness.

2.3 Basic variables

2.3.1 Actions and environmental influences

2.3.1.1 General

Addition after (1):

(102)P The partial safety factors for the actions for liquid retaining and containment structures are set out in Normative Annex B of EN 1991-4.

(103) Actions resulting from soil or water within the ground should be obtained in accordance with EN 1997.

2.3.2 Material and product properties

2.3.2.3 Properties of concrete with respect to watertightness

(101) If the minimum thicknesses of the member given in 9.11 (102) are used then a lower water-cement ratio may be required and, consideration should be given to a limitation to the maximum aggregate size.

Section 3 Materials

3.1 Concrete

3.1.1 General

(103) The effect of temperature on the properties of concrete should be taken into consideration in design.

NOTE Further information may be found in informative Annex K.

3.1.3 Elastic deformation

replace (5) by:

(105) Unless more accurate information is available, the linear coefficient of thermal expansion may be taken as equal to 10 x $10^{-6}K^{-1}$. It should be noted, however, that coefficients of thermal expansion of concrete vary considerably depending on the aggregate type and the moisture conditions within the concrete.

3.1.4 Creep and Shrinkage

Addition after application rule (5)

(106) Where the elements are exposed for substantial periods to high temperature (> 50 °C), creep behaviour is substantially modified. Where this is likely to be significant, appropriate data should generally be obtained for the particular conditions of service envisaged.

NOTE Guidance is given in Informative Annex K on the estimation of creep effects at elevated temperatures.

3.1.11 Heat evolution and temperature development due to hydration

(101) Where conditions during the construction phase are considered to be significant, the heat evolution characteristics for a particular cement should generally be obtained from tests. The actual heat evolution

should be determined taking account of the expected conditions during the early life of the member (e.g. curing, ambient conditions). The maximum temperature rise and the time of occurrence after casting should be established from the mix design, the nature of the formwork, the ambient conditions and the boundary conditions.

3.2 Reinforcing steel

3.2.2 Properties

(107) For reinforcing steels subjected to temperatures in the range -40 to +100 °C (if no special investigation is made) reference should be made to 1992-1-1, clause 3.2.2. For higher temperature, information is given in 3.2.3 of EN 1992-1-2. For relaxation at temperatures above 20 °C, see 10.3.2.2 in EN 1992-1-2.

3.3 Prestressing steel

3.3.2 Properties

(110) For prestressing strands subjected to temperatures in the range -40 to +100 °C (if no special investigation is made) the same values for strength and relaxation apply as for "normal temperatures". For higher temperatures, information is given in 3.2.4 of EN 1992-1-2.

Section 4 Durability and cover to reinforcement

4.3 Requirements for durability

Addition after 4.4.1.2 (13)

(114) Abrasion of the inner face of the walls of a silo may cause contamination of the stored material or lead to significant loss of cover. Three mechanisms of abrasion may occur:

— mechanical attack due to the filling and discharging process.

— physical attack due to erosion and corrosion with changing temperature and moisture conditions.

— chemical attack due to reaction between the concrete and the stored material.

(115) Appropriate measures should be taken to ensure that the elements subject to abrasion will remain serviceable for the design working life.

Section 5 Structural analysis

Addition after 5.11

5.12 Determination of the effects of temperature

5.12.1 General

(101) Rigorous analyses may be carried out using the provisions of 3.1.4 and Annex B of EN 1992-1-1 for creep and shrinkage.

(102) In storage structures, high temperature gradients may occur where the stored material is either self heating or is put into the structure at high temperature. In such circumstances calculation of the resulting temperature gradients and the consequent internal forces and moments will be necessary.

5.13 Calculation of the effects of internal pressure

(101) The internal pressure from solid materials acts directly upon the inner surface of the concrete. In the absence of a more rigorous analysis, internal pressure from liquids may be assumed to act at the centre of the retaining members.

Section 6 Ultimate limit states

Addition after 6.2.3 (8)

(109) The choice of strut angle in 6.2.3(2) for shear resistance should take into account the influence of any significant applied tension. Conservatively, cotθ may be taken as 1,0. The procedure in Annex QQ of EN1992-2 may also be used.

Addition after 6.8

6.9 Design for dust explosions

6.9.1 General

(101)P Where silos are designed to contain materials which may pose a risk of dust explosions, the structure shall either be designed to withstand the resulting expected maximum pressures or be provided with suitable venting which will reduce the pressure to a supportable level. The appropriate loads resulting from dust explosions are dealt with in EN 1991-4 and general considerations relating to design for explosions in 1991-1-7 however, the points in 6.9.2 (101) to (105) should be noted.

(102)P Fire expelled through a venting outlet shall not cause any impairment of the surroundings nor cause explosions in other sections of the silo. Risks to people due to flying glass or other debris shall be minimised.

(103) Vent openings should lead directly to open air through planned venting outlets, which reduce the explosion pressure.

(104) Venting systems should be initiated at low pressure and have low inertia.

(105) Actions due to dust explosions should be treated as accidental actions.

6.9.2 Design of structural elements

(101) The maximum pressures due to explosions occur in empty silo bins, however, the pressures in a partly filled silo bin combined with the corresponding pressures from the bulk material may lead to a more critical design condition.

(102) When inertia forces arise due to a rapid discharge of gas followed by cooling of the hot smoke, a pressure below atmospheric may occur. This should be taken into account when designing the encasing structure and members in the flow path.

(103) The elements forming a venting device should be secured against flying off and adding to the risks from flying debris.

(104) As pressure relief due to venting occurs, reaction forces are generated which should be taken into account in the design of structural members.